Smart Energy for Smart Cities

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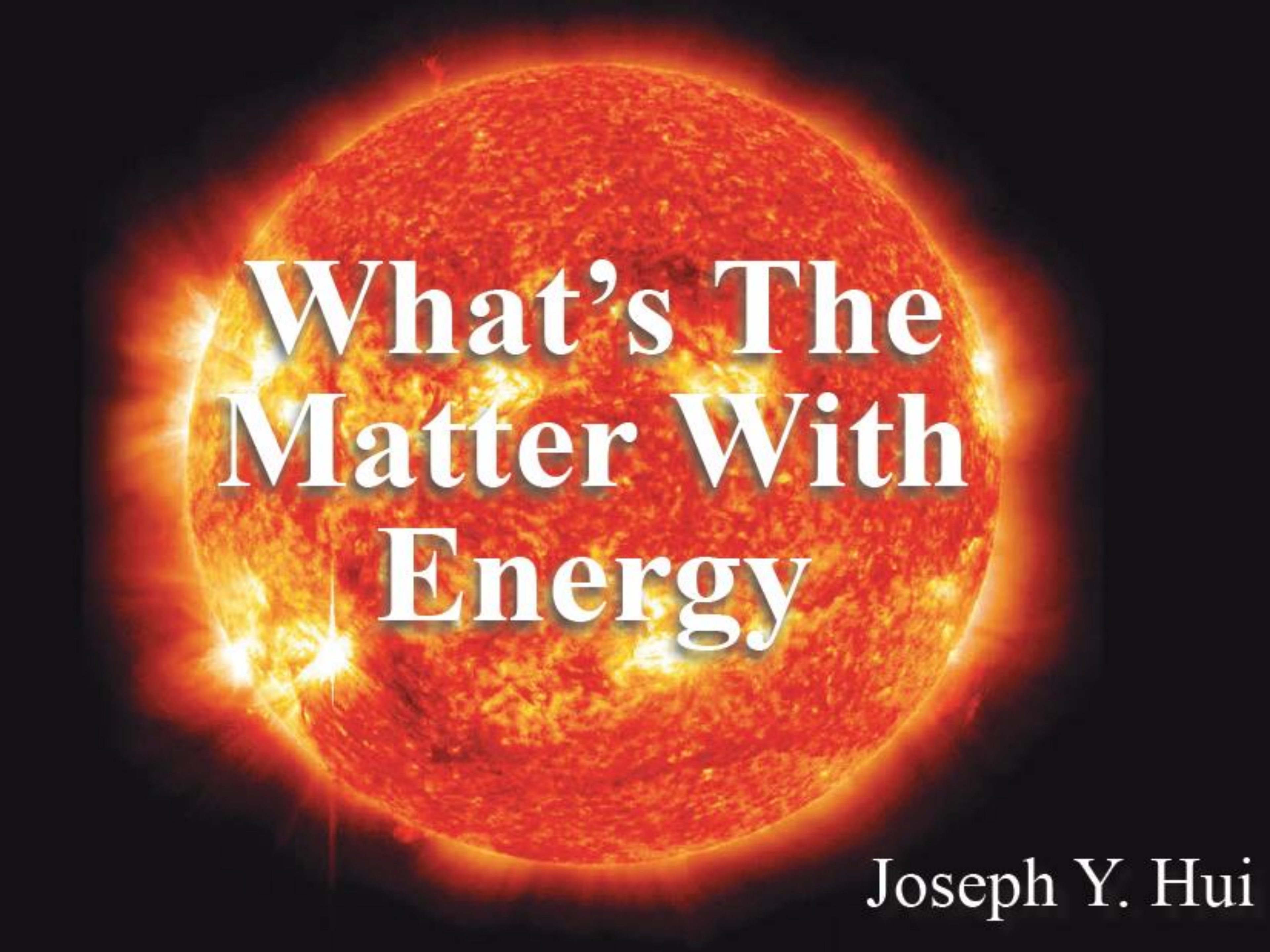
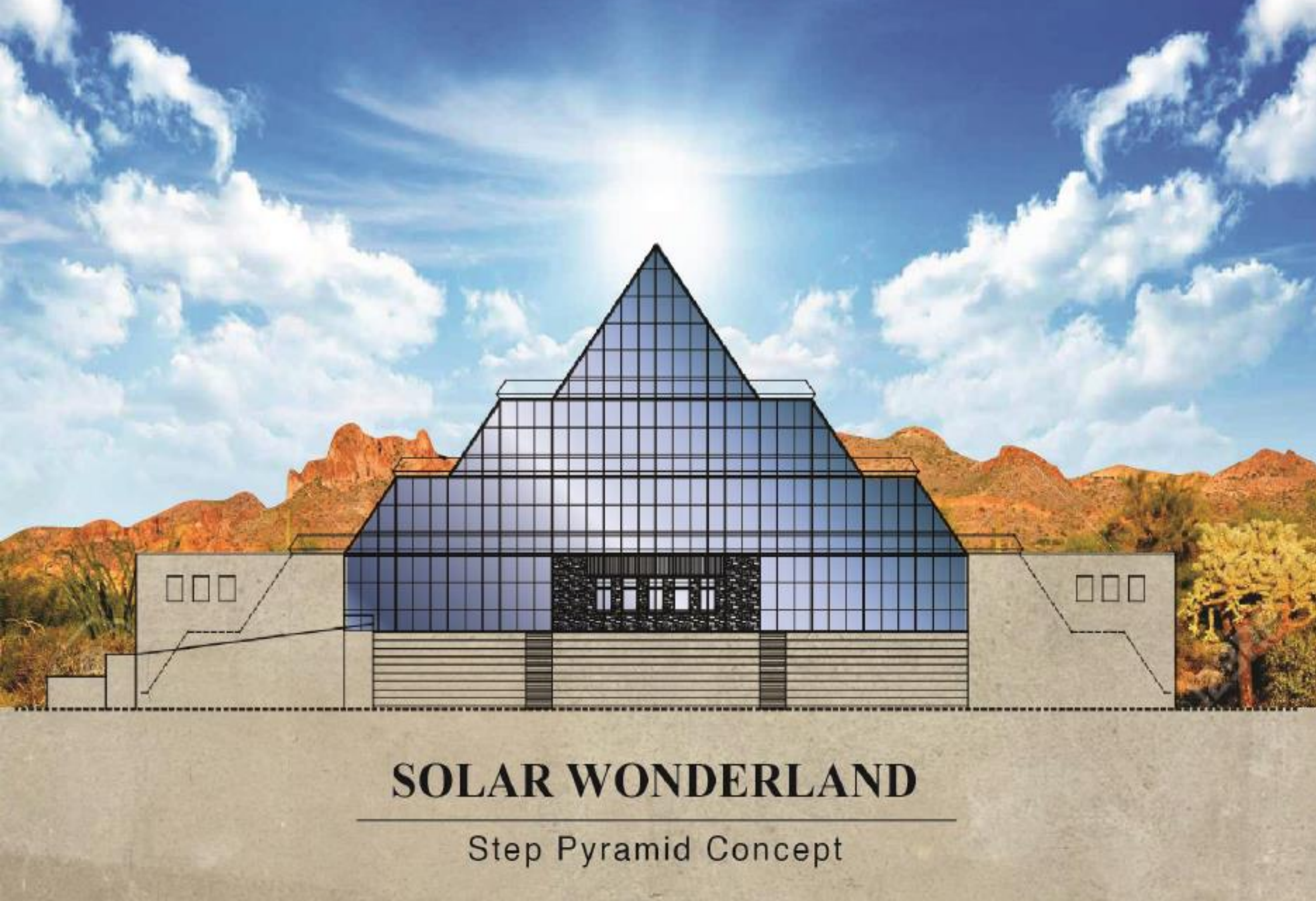

What's The Matter With Energy
Joseph Y. Hui

https://www.youtube.com/watch?v=pCNC1Cq-PyI



Earth in the hands of man

PE

Personal Energy

Solar Man Technologies

Lotus Awning (*Hybrid solar panel*)

Lotus Mobile (*Folding PV flowers*)

Lotus Butterfly (*Solar thermal*)

Hui Turbine (*Heat engine*)

Monarch disk motor (*Electric motor*)

Monarch SEV (*Solar electric vehicle*)

Monarch Tubeworm (*Desalination*)

Monarch 4-in-1 (*PV, water, heat, chill*)

Firefly Co-Gen (*Electricity, heat, chill*)

Solar Man Maglev (*Personal transport*)

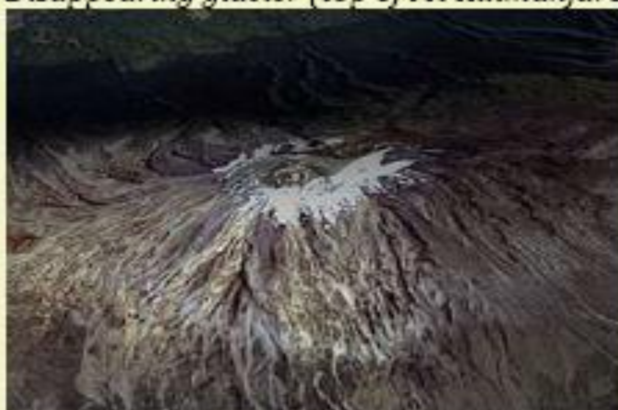
Solar Man Grill (*SolFood*)

Solar Man Ellipse (*SolFood*)

Effects of global warming

Melting polar ice cap

Disappearing glacier (top of Mt Kilimanjaro)



Ocean acidification due to CO_2

Living under the dark clouds of CG

Rooftop solar power (Solar Man and his panels)

Solar thermal power (Stirling Energy Systems)

Lotus Mobile parked at Butterfly Wonderland at the Odyssey of the Dessert, Pima tribal land, Arizona.

Lotus

Sun tracking and foldable solar flower power

Lotus Mobile
18 folding petals for $1kW$ PV power

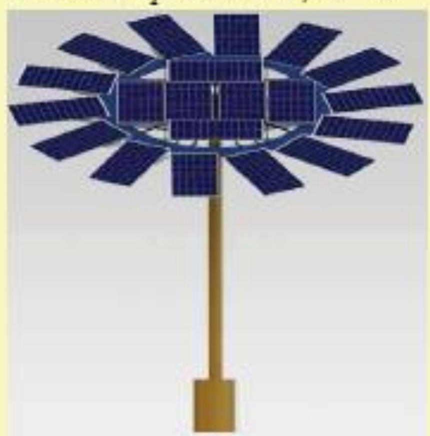
Lotus Heat
6 retractable panels each with $300W$ PV power plus $300W$ hot water power

Lotus Max
6 retractable panels and 14 folding panels
Total power $6kW$ PV and $6kW$ hot water

Lotus Garden
Al fresco dining under the Heat and Max

Lotus solar power systems
Lotus Heat with Lotus Water Chairs

Lotus Max open 28' wide, 25' tall



Lotus Max folded 16' wide, 25'tall

Concentrated solar thermal is better than solar photovoltaic

Concentrated solar thermal from Monarch Power

Hui turbine:
Exponential spirals for gas expansion
Pressure force on spiral, not impact force
Archimedes scroll spiral for gas compression

Joseph Y. Hui (1957 -) with the Hui spiral and turbine-generator that is similar in shape to the Whirlpool Galaxy

$$r = 10^{\theta/20\pi}$$
$$0 \le \theta \le 20\pi$$

Hui spiral

Units: radius $r\ (cm)$, $angle\ \theta\ (rads)$

Example: Hui turbine of $20cm$ diameter

Gas enters at $\theta = 0$, $r = 10^{0/20\pi} = 1cm$
Gas exits at $r = 10^{20\pi/20\pi} = 10cm$
Gas turns 10 times before turbine exit.

Angle between spiral tangent and radius is a self-similar and constant $\phi = 87.9°$

Length of spiral: $l \sim 1m$
Width of spiral: $w \sim 1cm$
Depth of spiral: $d \sim 1mm$

Hero of Alexandria (10 AD – 70 AD) made the first bladeless heat turbine with very low efficiency

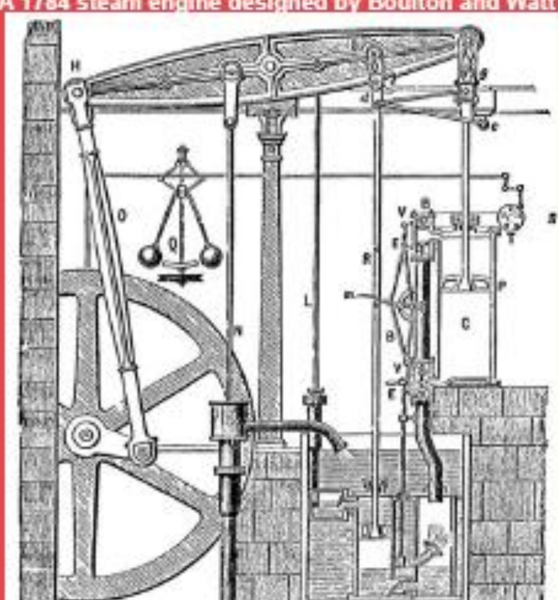
James Watt (1736-1819).

Steam Engine (Rankine cycle engine):
Poor efficiency due to evaporation
Steam needs superheating and pressure
Condenser uses large amount of water

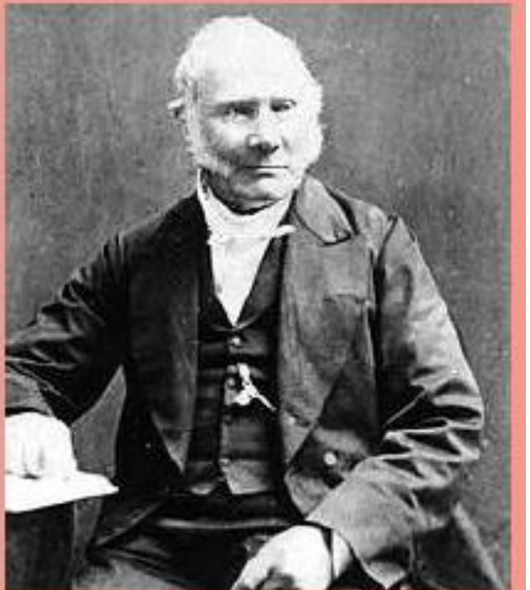
watt

Power: $1W = 1J/s$

A 1784 steam engine designed by Boulton and Watt



Railroad opened up the American Wild West



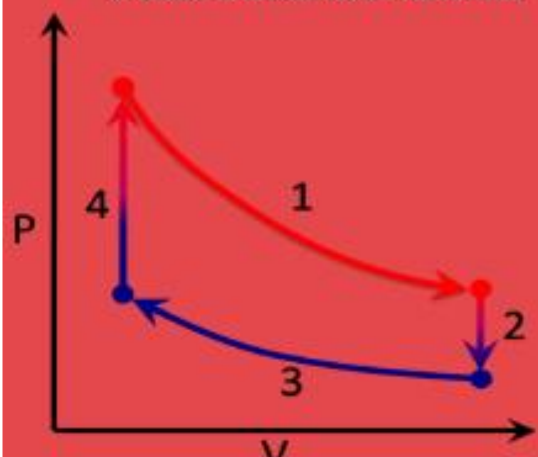
Reverend Dr. Robert Stirling (1790-1878)

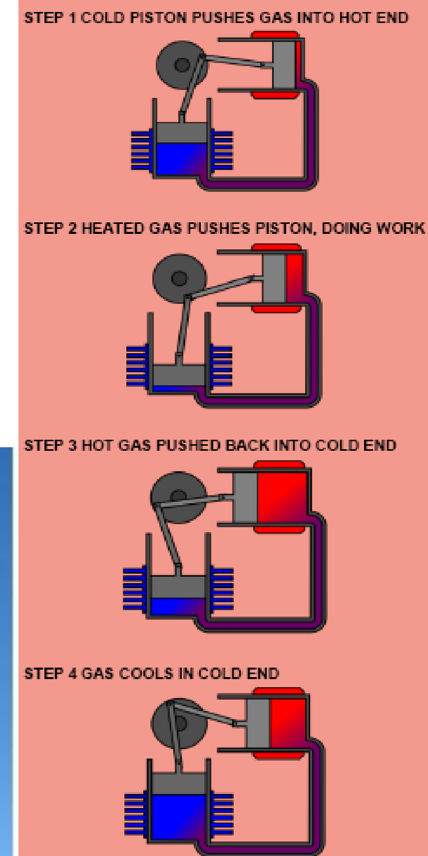
Stirling Engine:
Constant pressure cycles 2 and 4
Uses air or hydrogen

Air

Stirling cycle working fluid

1. ISOTHERMAL EXPANSION
2. SAME VOLUME HEAT REMOVAL
3. ISOTHERMAL COMPRESSION
4. SAME VOLUME HEAT ADDITION





Stirling Energy System used solar dish to generate electricity

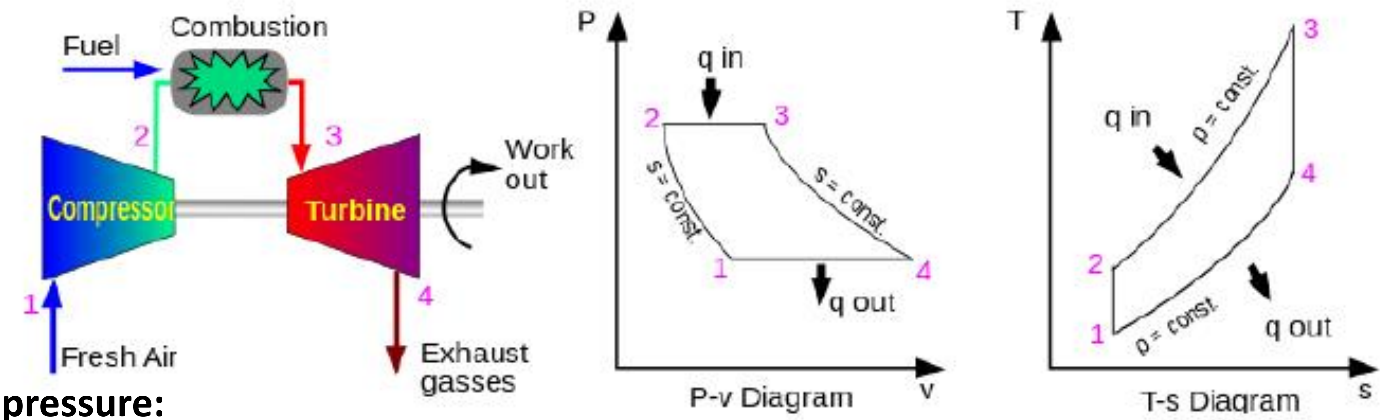
BRAYTON – FATHER OF MODERN GAS TURBINES

George Bailey Brayton (1830-1892)

Brayton Cycle
Heat Engine

(Similar to Carnot cycle)

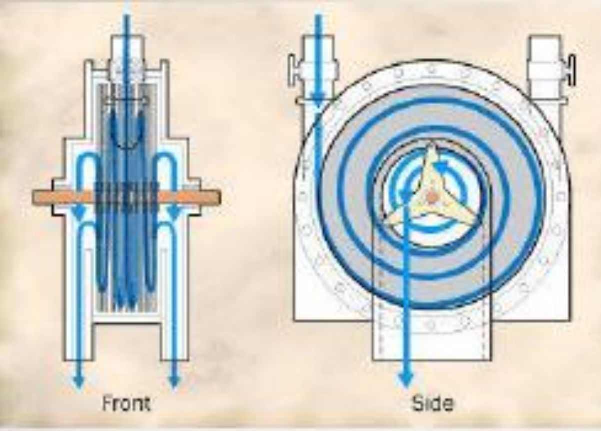
- **Isobaric compression (not isothermal)**
- **Adiabatic expansion (same as Carnot)**
- **Isobaric expansion (not isothermal)**
- **Adiabatic expansion (same as Carnot)**
- **Efficiency depends on pressure:**



$$\varepsilon = 1 - \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = 1 - \left(\frac{P_1}{P_2}\right)^{\frac{2}{7}}; \qquad \text{if } \frac{P_1}{P_2} = \frac{1}{20} \text{ then } \varepsilon = 1 - \left(\frac{1}{20}\right)^{\frac{2}{7}} = 57.5\% \text{ with } \frac{V_1}{V_2} \sim 8$$

Tesla Turbine:
Gas injected from edge spiraling in.
Drags turbine disks by gas viscosity.

Tesla turbine does not work well!



Fluid flow in Tesla turbine based on Tesla's patent drawing

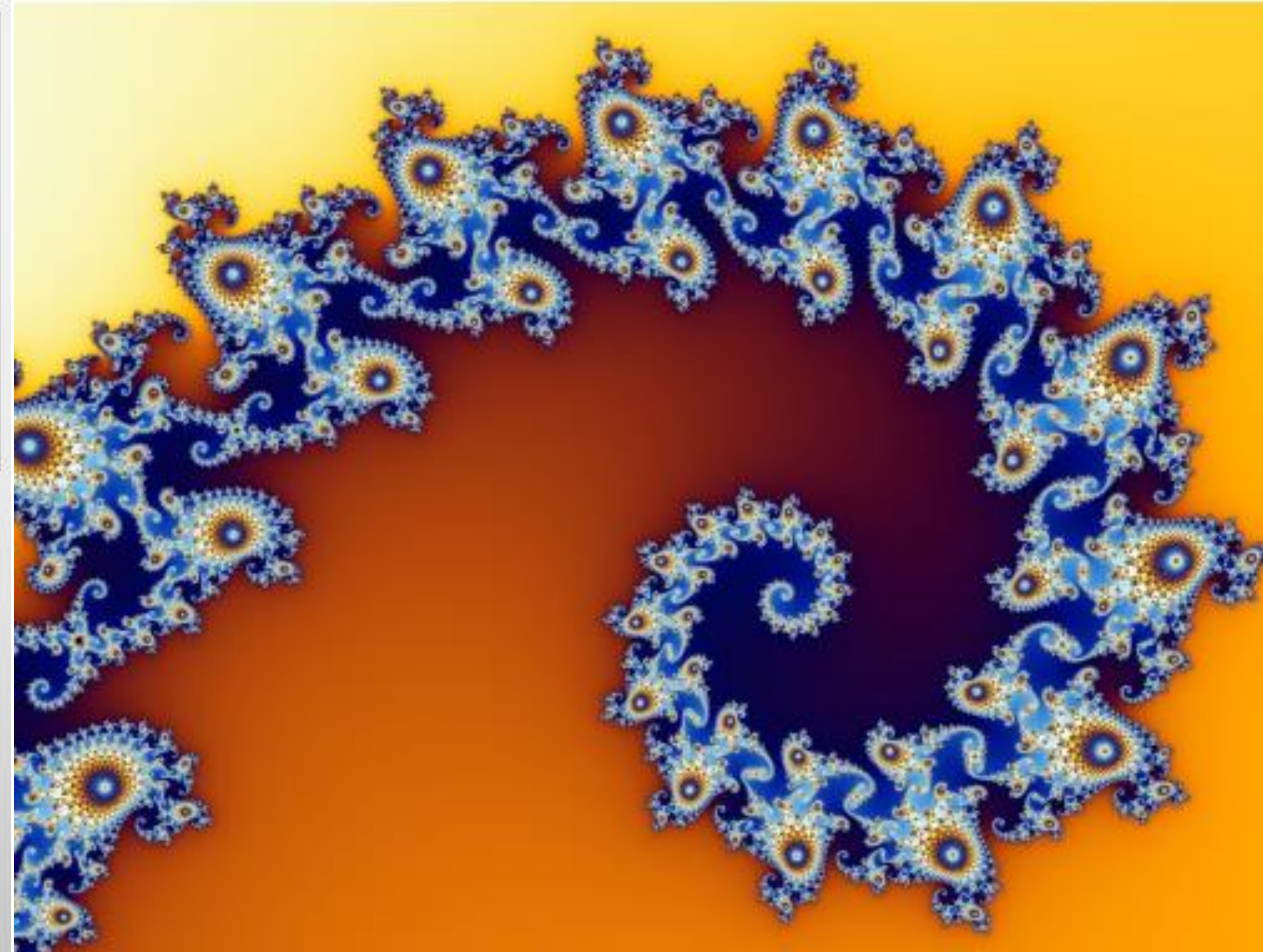
$$\theta = \frac{1}{b} \ln \frac{a}{r}$$

Logarithmic spiral

Units: initial radius a (cm).
Logarithm is based $e = 2.71828$
Angle turned θ (rad) at radius r (cm)

Example: Spiral is $\theta = 10 \ln 10/r$. Gas enters at $r = 10cm$ and exits at $r = 1cm$, after $\theta = 10 \ln 10 = 23.0\ rad = 3.66\ turns$

Jakob Bernoulli (1654-1705)



$$r = ae^{b\theta}$$

Exponential spiral

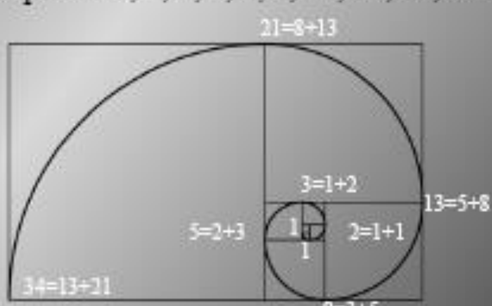
Units: $r, a(m), b(rad^{-1}), \theta(rad)$

Exponential growth: $e = 2.718281828$

Golden ratio: $\varphi = \frac{1+\sqrt{5}}{2} = 1.618$

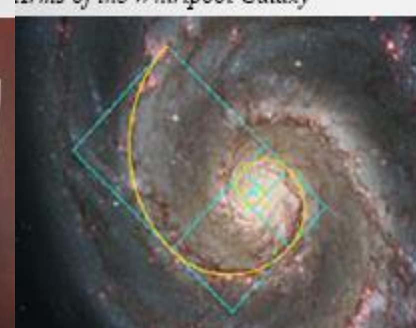
Example: The golden spiral $r = e^{0.306\theta}$ has radius r grow by $\varphi = e^{0.306\pi/2} = 1.618$ for every right angle (90°, $\pi/2$ radian) turned.

Example: The Fibonacci spiral is formed by the sequence 1, 1, 2, 3, 5, 8, 13, 21, 34, etc.



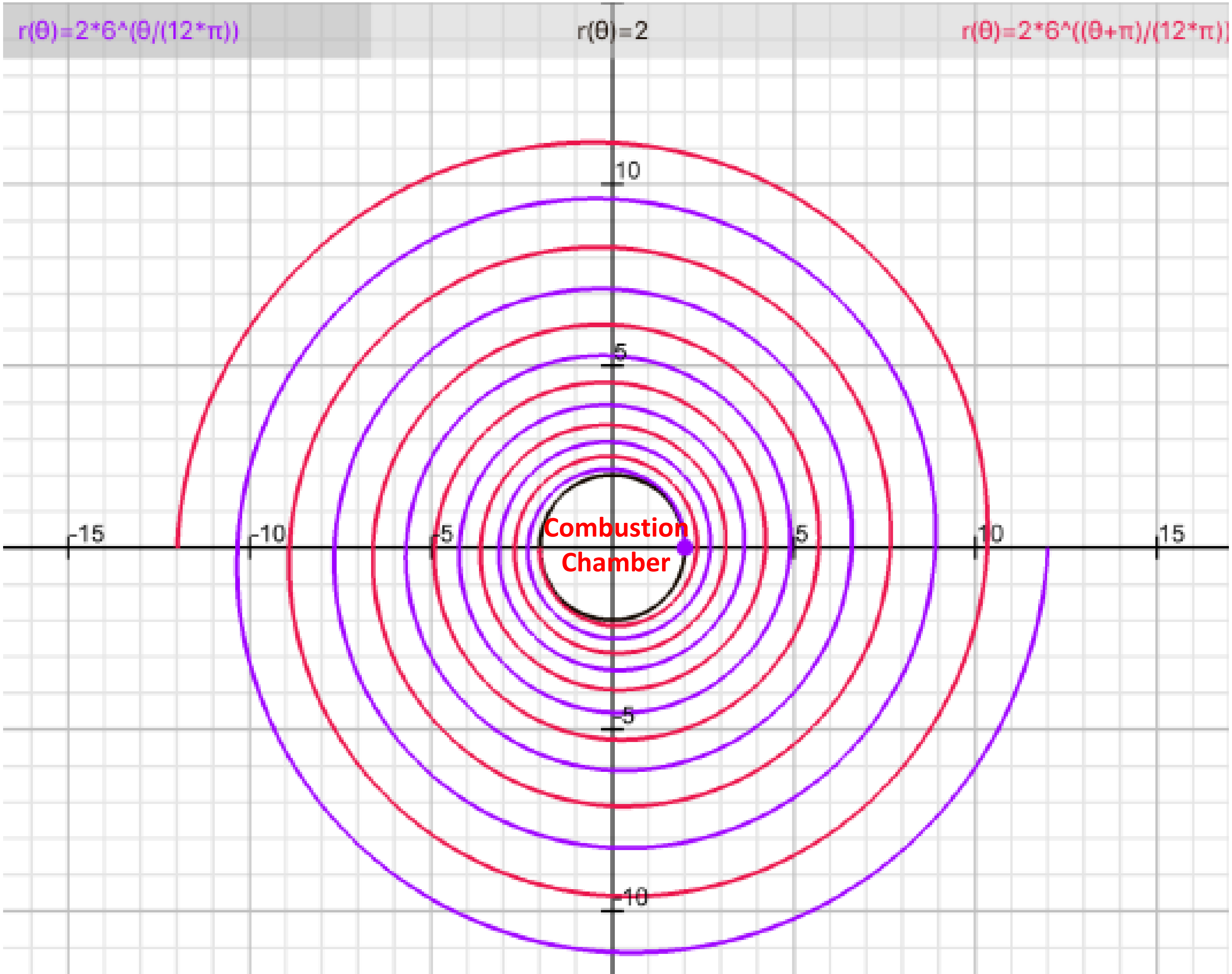
Cross section of nautilus shell

Arms of the Whirlpool Galaxy

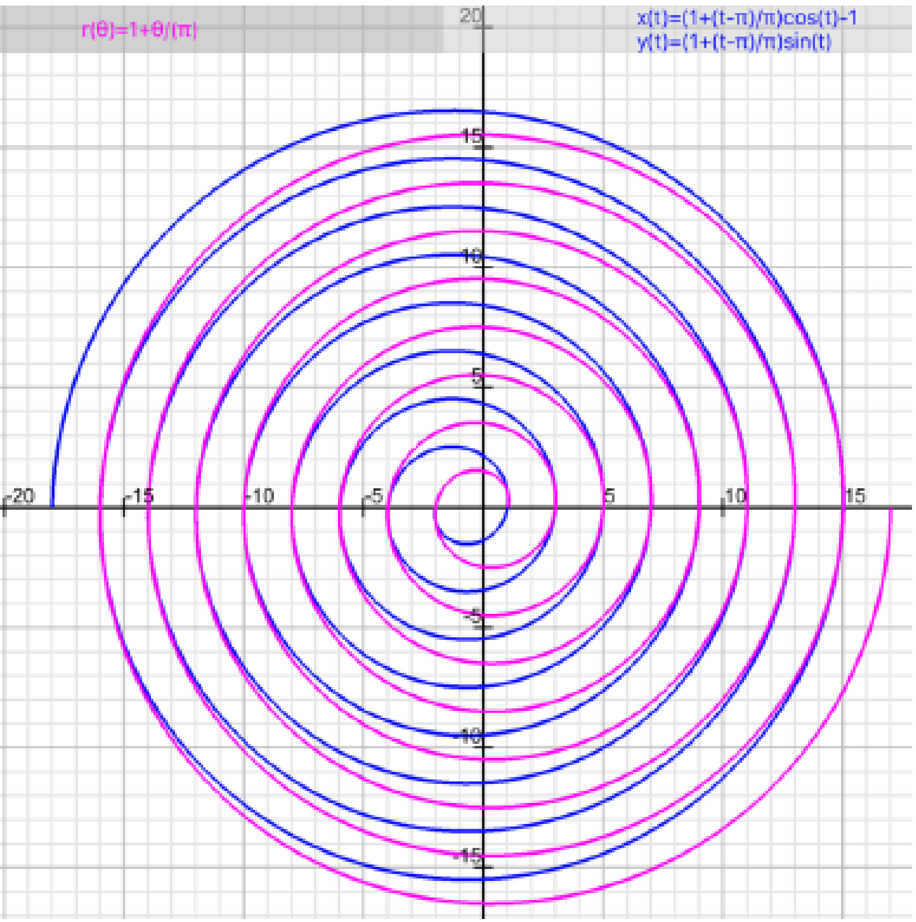


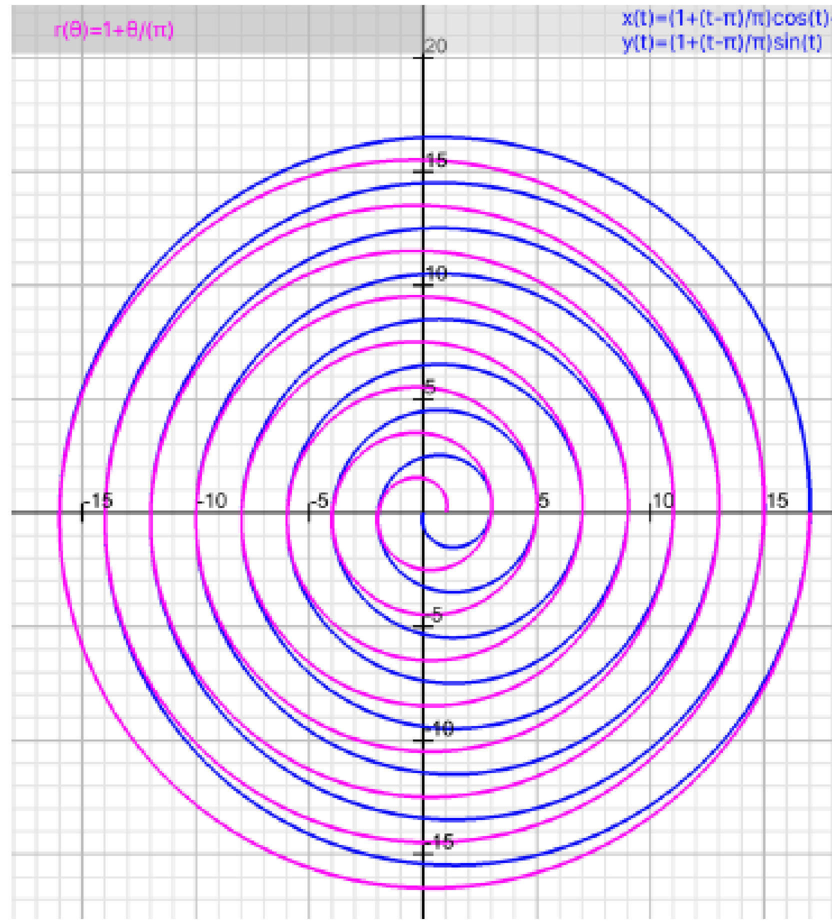
Arms of hurricane with inward gas flow

Exponential Spiral – Self Similarity for Max Torque

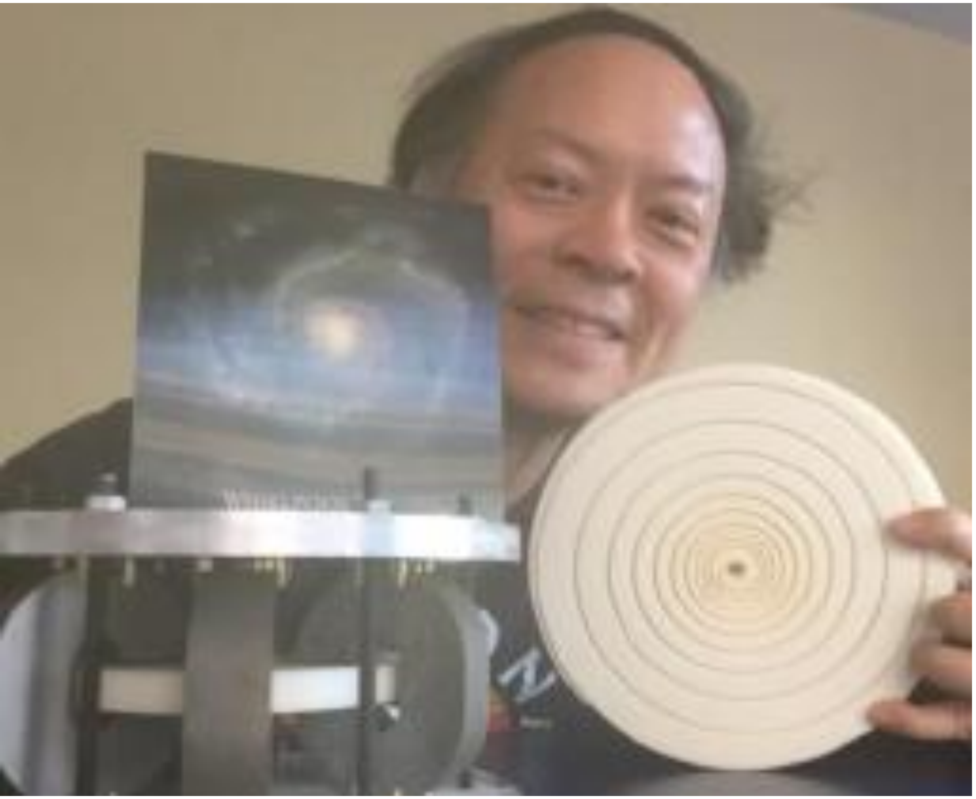


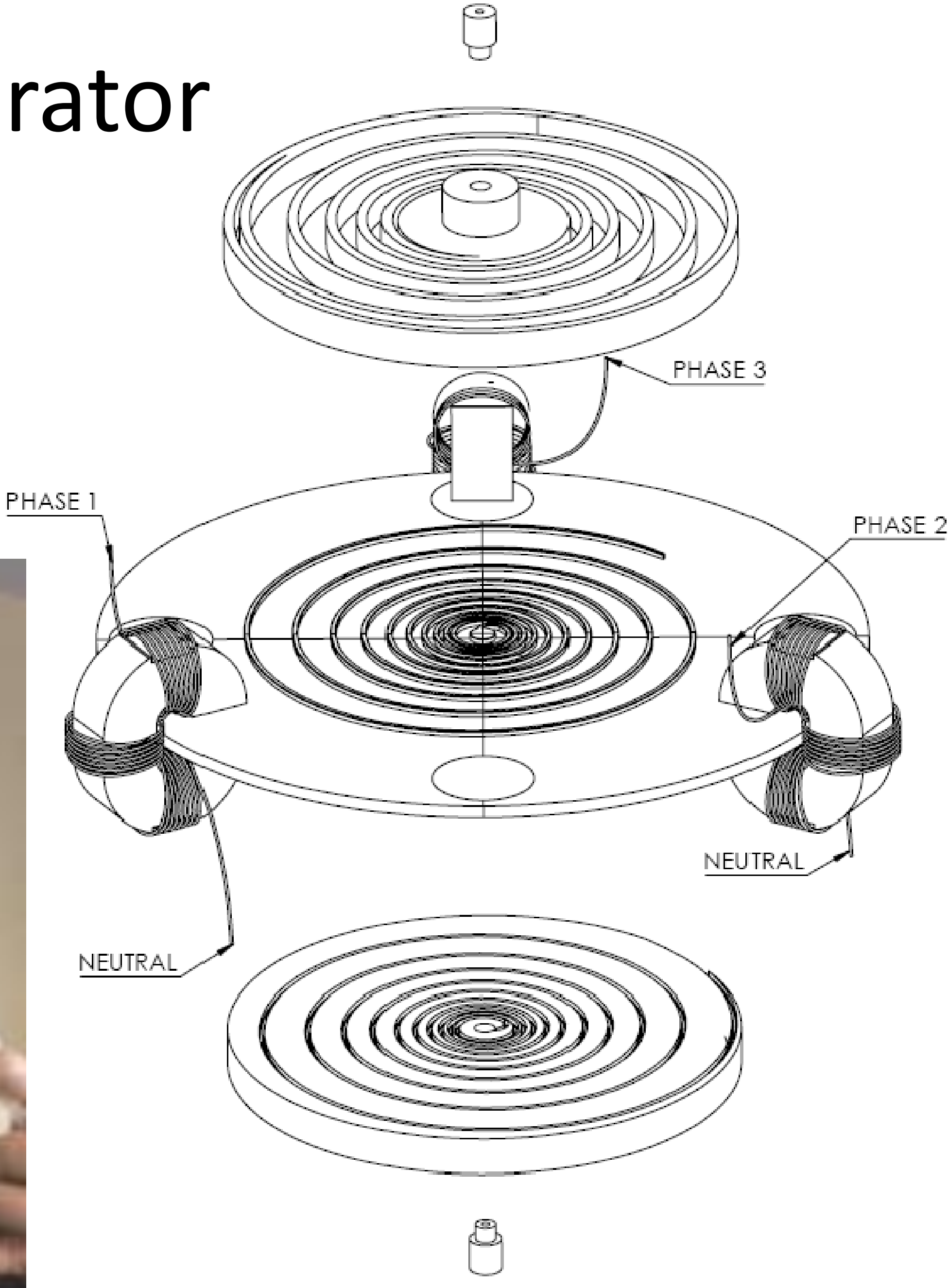
Archimedes Scroll Compressor – No Value, No pistons



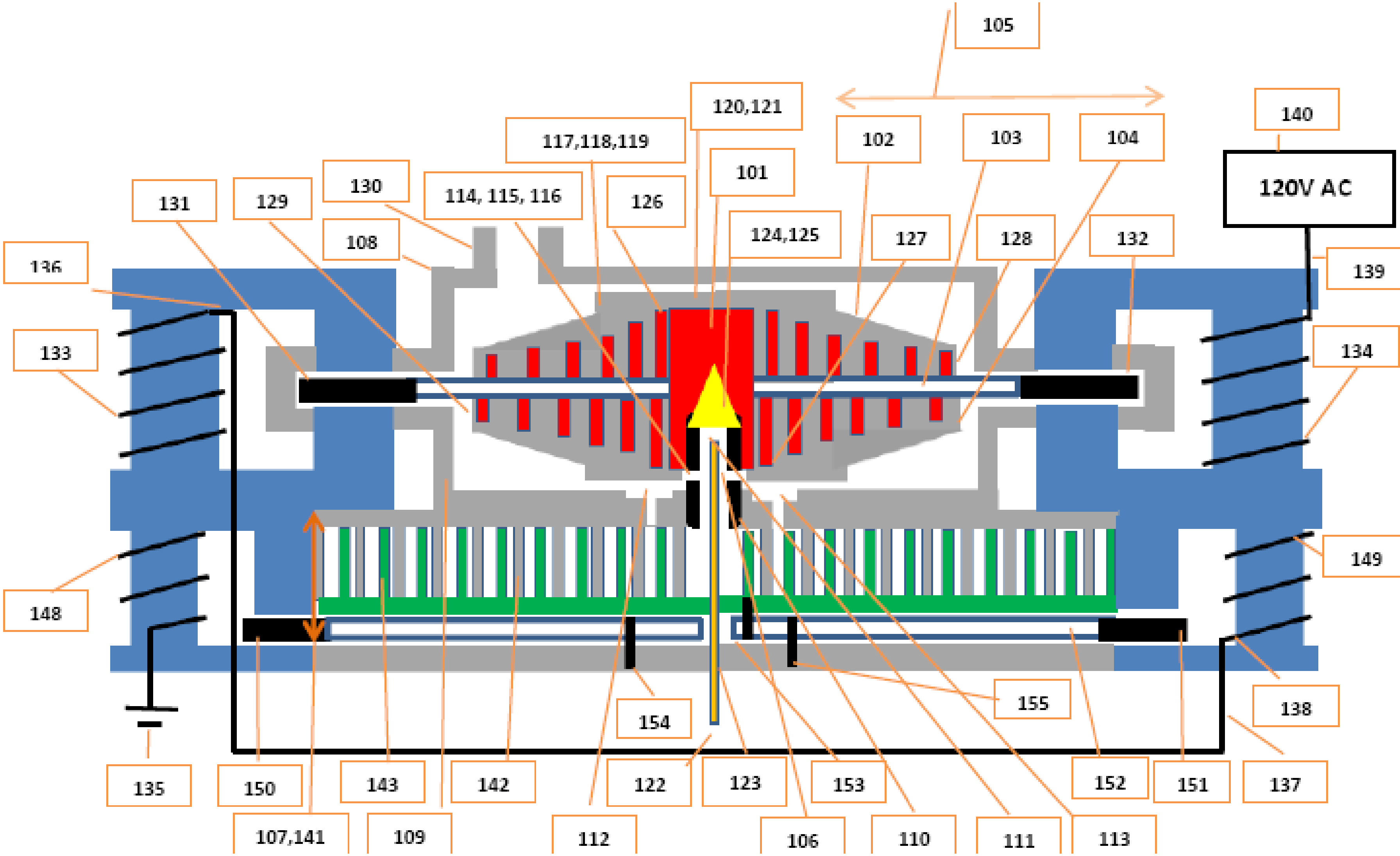


Coaxial Turbine-Generator

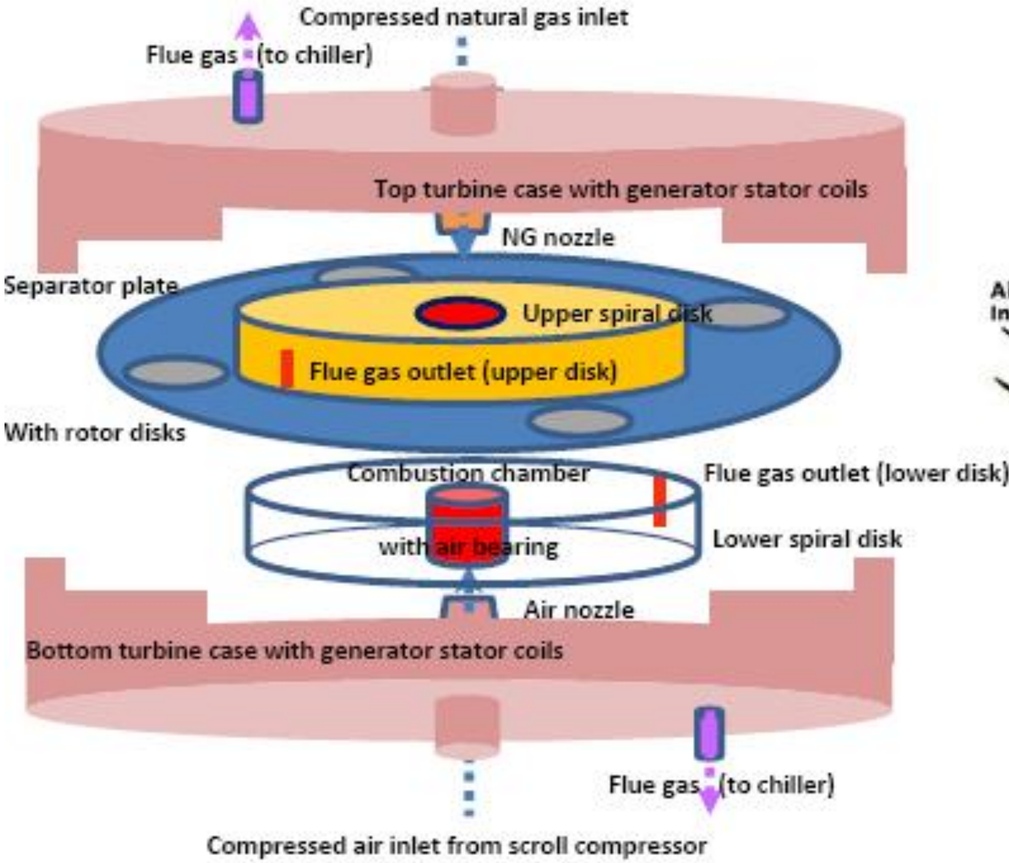


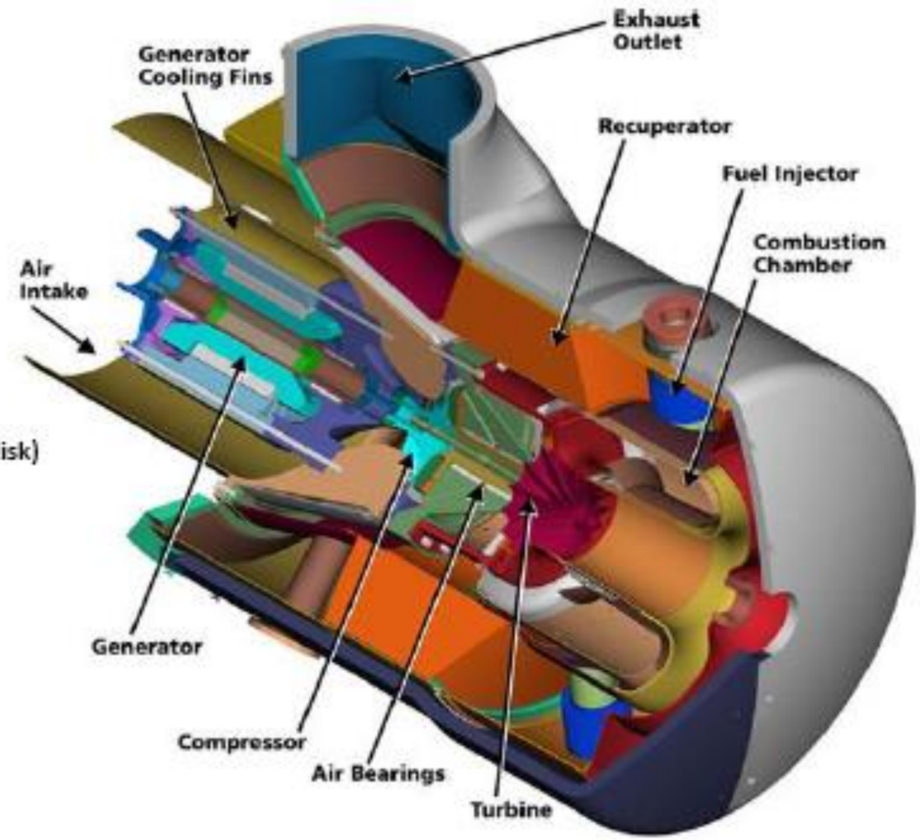


Integrated Compressor-Expander, Generator-Motor

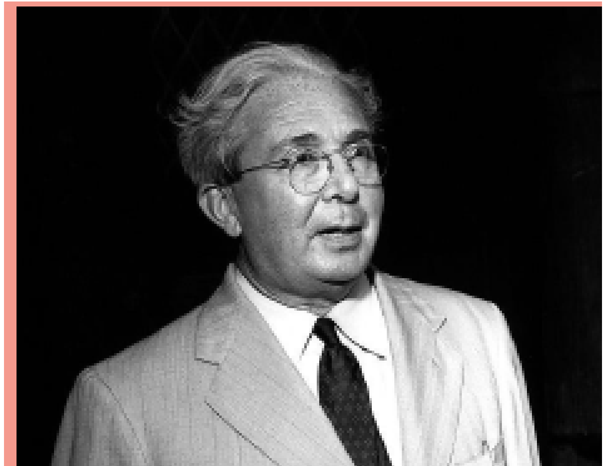


Competition – Capstone Turbine C30





Hui turbine generator (exploded view left) and Capstone turbine generator (right)



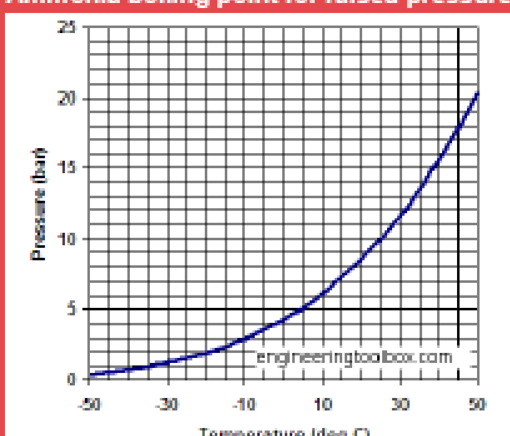
Leo Szilard (1898-1964)

NH_3

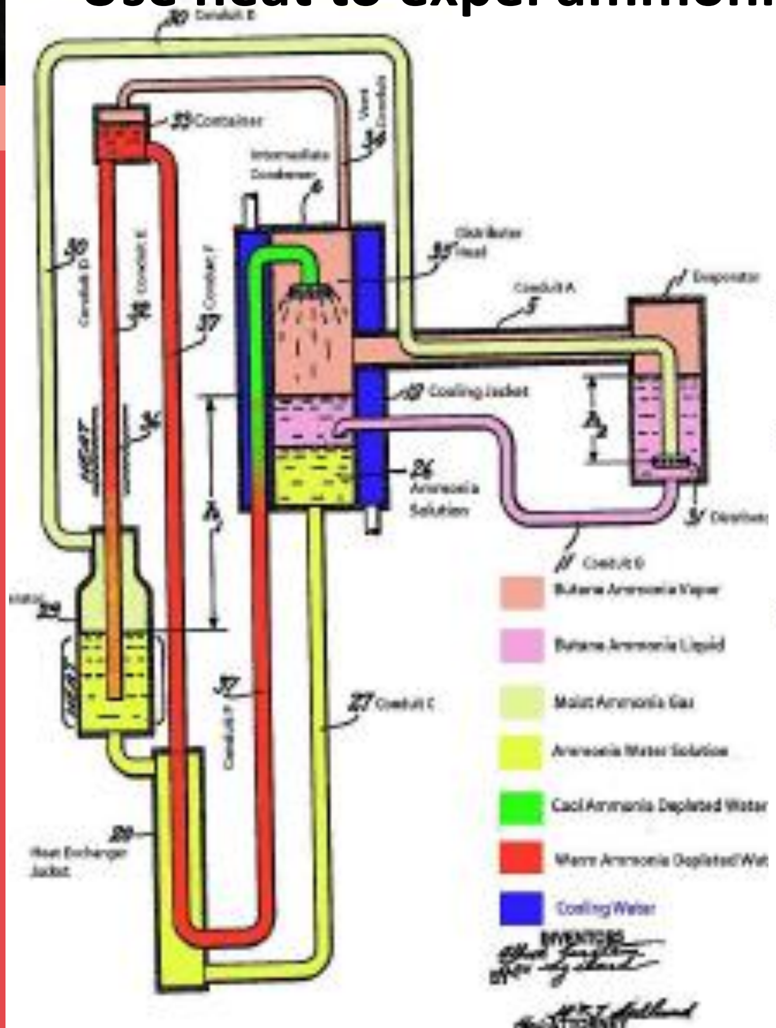
Ammonia as refrigerant

Molecular weight: 17
Boiling point: −33.3°C
Solubility in water by weight:
47% at 0°C, 31% at 25°C, 18% at 50°C

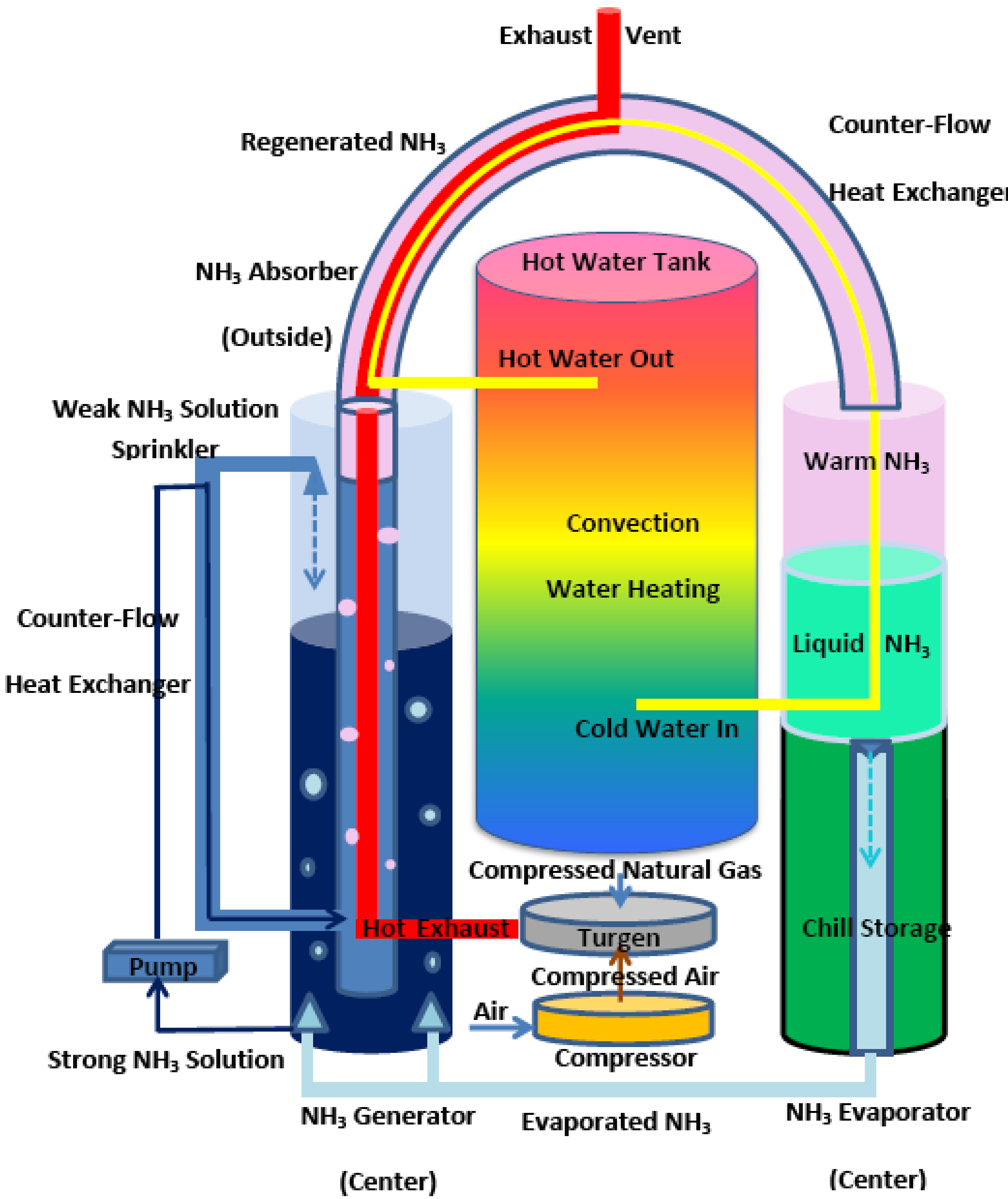
Ammonia boiling point for raised pressure



Einstein-Szilard Ammonia Chiller:
Condense ammonia under high pressure
Evaporate ammonia to chill
Absorb ammonia in water
Use heat to expel ammonia under pressure

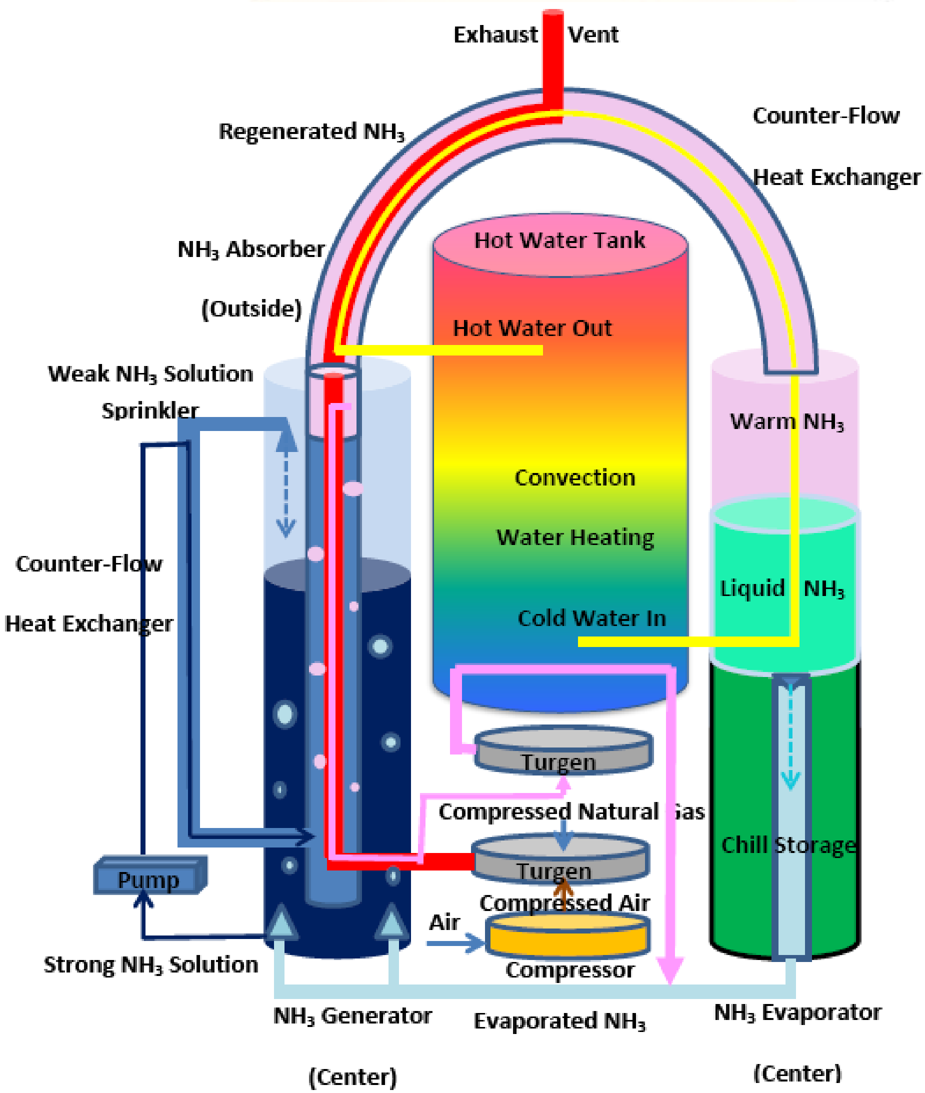


Combined Cooling, Heat, Power CCHP



Firefly Trigen (mCCHP, nCCHP) vs Capstone Turbine C30

A COMPARISON OF TWO MICROTURBINES



Hui turbine and generator (top left), Firefly Trigen (bottom left) and Capstone Turbine C30 unit (right)

Comparing Firefly with Capstone Turbines

Features	Firefly Trigen ® nCCHP	Firefly Trigen ® mCCHP	Capstone Turbine C30
Turgen size	0.3m Di x 0.1m H disk	0.6m Di x 0.2m H disk	Significant size in system
Principle	Gas presses turbine spiral. Turbine spins in reaction. Combined generator/compressor/turbine. No spin axle.		Nozzle speeds gas to impact turbine blades. Spin axle.
System size	0.3m Di x 0.6m H	0.6m Di x 1.2m H	0.76m Wx1.5m Dx1.8m H
Weight	Dry ~ 5kg, wet ~25kg	Dry ~ 50kg, wet ~250kg	405 kg, grid connect 578kg
Power output	1kW 120VAC, 12VDC	10kW or 15kW 3-phase 120VAC	30kW 3-phase 480V AC
Efficiency	1kW electricity 40%	10kW electricity 40%; 15kW 60%	30kW electricity 26%
Price ($=US$)	Trigen $799 ($0.8/W)	10kW $7999, 15kW$9999 ($0.8/W)	$48,000, ($1.6/W)
Chill output	1kW of chilled water	10kW of chilled water	No chill or hot water output
Heat output	1kW of hot water	10kW of hot water	~100kW heat in flue gas
Fuel type/use	Propane: ¼ m^3/hr	Natural gas: 2.5m^3/hr	Natural gas: 12m^3/hr
Fuel cost ($2/GGE)	$0.1/kWh	$0.09/kWh; Trigen Plus $0.06/kWh	$0.2/kWh
Fuel air ratio	1:30 for propane	1:10 for natural gas (propane 1:30)	1:80 for natural gas
Flue gas	$>$ 500°C for NH_3 boiler, either for chiller or CCGT		275°C at 0.31kg/s.
Compressor	8:1 Archimedes scroll spiral with magnet coupling to turbine		Centrifugal compressor
Expander	1:6 exponential spiral grid-tied (3,600rpm grid tied at 60Hz)		Impact turbine (96,000rpm)
Air bearing	High pressure compressed air as bearing		Compressed air bearing
Generator	Synchronous motor. Shared stator for turbine/compressor		Asynchronous motor
Grid-tie	Grid regulated (60Hz). No inverter is needed		Needs converter/inverter
Batteries	Four 3.7V lithium ion	Forty 3.7V lithium ion	No battery storage
Exterior and look	Clear plastic (polycarbonate) cylindrical. Multi-color liquids.		Industrial metal cubic. Grey

Monarch 4-in-1 gives power, heat, chill, water:
Einstein-Szilard NH_3 chiller.
Heat CO_2 to drive Hui turbine for power.
Absorb both NH_3 and CO_2 in water.
$(NH_4)_2CO_3$ solution for FO desalination.
Removes NH_3 and CO_2 by heat for clean water

Ammonium carbonate, also known as Hirschhorn salt.

$(NH_4)_2CO_3$

Ammonium Carbonate

Chemical properties:

Molar weight: $96.09 g/mol$

Density: $1.50 g/cm^3$

Melting point 58°C

Solution into water:

$$(NH_4)_2CO_3 \rightarrow 2\,NH_4^+ + CO_3^{2-}$$

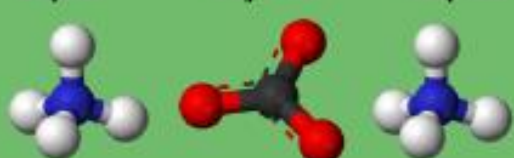
Decomposition of solution:

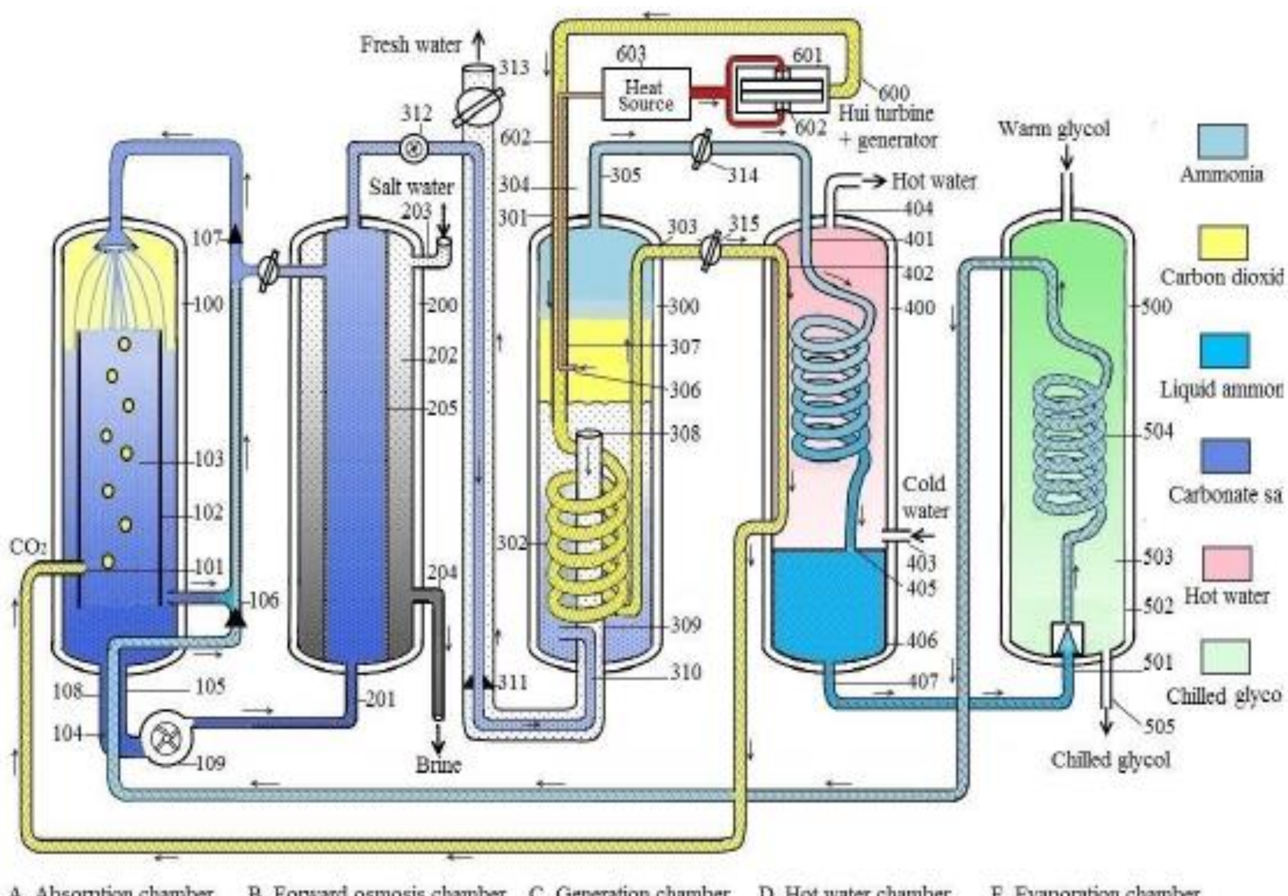
$$(NH_4)_2CO_3 \rightarrow NH_3 + (NH_4)(HCO_3)$$

Melting and decomposition into gases:

$$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$$

NH_4^+ ion CO_3^{2-} ion NH_4^+ ion





“Let’s live a comfortable but sustainable life.” – Solar Man

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